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The effects of soil fumigation on the growth and mineral nutrition of weeds and crops

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ABSTRACT. Weeds and soil microorganisms interact with each other in the soil/root interface, promoting the development and establishment of both. The objective of this study was to evaluate the growth and nutrient accumulation in eight species of weeds (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cenchrus echinatus* L., *Conyza bonariensis* L., *Echinochloa crus-galli* L., *Eleusine indica* L. *Ipomoea grandifolia* L. and *Lolium multiflorum* L.) and in bean and corn crops grown for 50 days in a substrate fumigated with methyl bromide. Assessments relating to the height, leaf area, leaf number, dry weight of shoots and roots and relative content of nutrients were carried out 50 days after seedling emergence. A positive effect of soil fumigation was observed on the growth, leaf number, leaf area, plant height and accumulation of nutrients in monocot weeds in relation to dicots. *Conyza bonariensis* was the most affected by soil fumigation, with levels of dry matter, leaf number, leaf area, height and accumulation of nutrients approximately 50% lower than plants grown in normal soil. Fumigation also influenced the growth cycle of the plants, which was lower for *B. pilosa*, *E. indica* and *C. echinatus*. We also observed a 20 and 30% lower phosphorus accumulation in *Bidens pilosa* and *Conyza bonariensis*, respectively, when grown in the sterilized soil. Overall, the bean and corn crops were less affected by soil fumigation than the weeds.

Keywords: rhizosphere, soil microorganisms, *Conyza bonariensis*, methyl bromide.

Efeito da fumigação do solo no crescimento e nutrição mineral de plantas daninhas e culturas

RESUMO. Plantas daninhas e microrganismos do solo se interagem na interface solo/raiz promovendo vantagens para o desenvolvimento e estabelecimento de ambos. Objetivou-se com este trabalho avaliar o crescimento e o acúmulo de nutrientes em oito espécies de plantas daninhas (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cenchrus echinatus* L., *Conyza bonariensis* L., *Echinochloa crus-galli* L., *Eleusine indica* L., *Ipomoea grandifolia* L. e *Lolium multiflorum* L.) e nas culturas de feijão e milho, cultivadas, por 50 dias, em substrato fumigado com brometo de metila. Avaliações referentes à altura, área foliar, número de folhas, matéria seca da parte aérea e das raízes e teor relativo dos nutrientes, foram realizados aos 50 dias após emergência das plântulas. Observou-se efeito positivo da fumigação do substrato no crescimento, número de folhas, área foliar, altura de plantas e acúmulo de nutrientes nas plantas daninhas gramíneas em relação às dicotiledôneas. *Conyza bonariensis* foi a mais afetada pela fumigação do solo, apresentando índices de matéria seca, número de folhas, área foliar, altura e acúmulo de nutrientes em torno de 50% menores em relação às plantas crescidas em solo normal. A fumigação influenciou também o ciclo vegetativo das plantas, sendo este menor para as espécies *B. pilosa*, *E. indica* e *C. echinatus*. Observou-se, ainda, acúmulo de fósforo 20 e 30% menor em plantas de *Bidens pilosa* e *Conyza bonariensis*, respectivamente, quando cultivadas em solo esterilizado. As culturas de feijão e milho foram menos afetadas pela fumigação do solo em comparação às plantas daninhas.

Palavras-chave: rizosfera, microrganismos do solo, *Conyza bonariensis*, brometo de metila.

Introduction

Even after the adoption of integrated crop management, including no-tillage and crop rotation techniques, several steps for the crops can still change the ecological balance. Regarding the use of pesticides in Brazil, herbicides lead sales, accounting for approximately 45% of the market (SINDAG, 2010), due to the diversity and aggressiveness of the species infesting the major crops. There has been an increase in the concern about the sustainability of agricultural production systems, prioritizing those techniques that prevent or reduce the use of chemical controls. The main weed species on plantations in the Brazilian Cerrado are highly aggressive and have a rapid capacity of adaptation, establishment and perpetuation. Several characteristics of these species make them more efficient in procuring nutrients from the environment, and they dominate crops when grown in competition. It has been reported that these species possess a high capacity for seed production, differentiated germination capacity and rapid initial development; in addition, the seeds remain viable in the soil for extended periods and are dispersed by several different mechanisms.

Recent studies have emphasized the contribution of soil microorganisms in the processes of nutrient release (DUDA et al., 2003; SILVA; NAHAS, 2002). Thus, acknowledging the complexity of the relationships between the soil microorganisms and plant species in a given ecosystem, it is expected that the adaptability characteristics of weeds are influenced directly by soil microorganisms.

The edaphic microscopic community is highlighted by an adaptive versatility to changing factors, such as pH, moisture, the concentration of a particular element and temperature, and it is often protected and stimulated by the plant community present (SILVA; NAHAS, 2002). Thus, a significant portion of the competition between plants occurs below the soil surface, where the modes of the activation of gene expression in response to competition for water and nutrients have not yet been fully elucidated (BIANCHI et al., 2006) and where the root system plays a key role in the competitive process (RIZZARDI et al., 2001).

Once established, the competition between plants and the existence of an association with soil microorganisms may be decisive, especially for absorbing nutrients that are difficult to intercept, such as phosphorus. According to Zak et al. (2003), the survival and productive capacity of plants are conditioned to the soil microorganisms associated with them.

However, Scher and Baker (1980) and Kao and Ko (1983), aiming to identify the effects of methyl bromide in soil, have found that soil treatment with this gas kills pathogenic fungal spores, affecting the soil suppressiveness, a quality that promotes plant growth because the microbiota are efficient in the use of organic sources, oxygen and, especially, minerals. Thus, the relationship between plants and microorganisms does not favor the absorption of elements by the roots of weeds, jeopardizing the development of some species that do not depend on mutualistic relations. Therefore, as a function of their growth, plants may respond differently to the fumigation of the substrate.

The study presented here aimed to evaluate the development of and quantify the accumulation of nutrients in the shoots of weeds and crops in soil subjected to fumigation.

Material and methods

The experiment was conducted in a greenhouse belonging to the Department of Microbiology at the Federal University of Viçosa, using soil samples classified as Red-Yellow Ultisol.

The chemical and physical analysis of this soil was carried out previously, with the following results: pH (water) of 5.1; organic matter content of 2.18 dag kg^{-1}; P, K and Ca of 0.5, 16 and 0.1 mg dm^{-3}, respectively; and contents of Mg, Al, H + Al and CTC_{total} of 0.0, 1.1, 6.18 and 6.09 $cmol_c$ dm^{-3}, respectively. Sieve analysis showed the following proportions, classifying the sample as sandy-clayey: clay, 39%; silt, 13%; fine sand 15% and coarse sand, 33%. The soil samples were fumigated for 72 hours with BROMEX® (methyl bromide 98% + chloropicrin 2%) at a dosage of 2.5 cm^3 L^{-1}, using a box made of polyvinyl chloride (PVC). The substrate was then transferred to pots with a capacity of 6.0 L with no fertilization; pots were also filled with the same soil, unfumigated. The seed for each species were sterilized with sodium hypochlorite at 10% for 10 minutes and immersion in 70% alcohol for 40 seconds, followed by three washes with distilled water (AGRIOS, 1997). Ten seeds were sown in each pot.

A total of 20 treatments, consisting of combinations of eight plant species, including the common weeds of major tropical crops (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cenchrus echinatus* L., *Conyza bonariensis* L., *Echinochloa crus-galli* L., *Eleusine indica* L., *Ipomoea grandifolia* L. and *Lolium multiflorum* L.) and two crop plants (*Phaseolus vulgaris* L. var. Ouro Vermelho and *Zea mays* L. var. UFV - M100), in fumigated (or not) substrate. The experimental units were arranged in a completely randomized design, with four replications for each treatment.

After seedling emergence, thinning of the plants was performed, leaving two seedlings per pot. During the experiment, all phytosanitary precautions were taken, and the plants were irrigated with distilled water.

At 50 days after sowing, the following assessments were performed in all of the species: plant height, leaf number, leaf area and dry mass of roots. For those species showing changes in the vegetative/reproductive phenological stadium prior to that date, the assessment also included counting the number of days to flowering. At harvest, the shoots of the plants were detached and placed in an incubator at 65°C until they reached a constant weight; the material was weighed and subsequently ground in a Willey-type mill. Samples of this ground plant material were subjected to nitro-perchloric digestion. Next, determinations were made for the concentrations of phosphorus (P) by the modified method of vitamin C (BRAGA; DE FELIPPO, 1974), potassium (K) by flame photometry (SARRUGE; HAAG, 1974), sulfur (S) by turbidimetric sulfate (JACKSON, 1958) and calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) by atomic absorption spectrometry (AOAC, 1975).

For each species, the values were converted to percentage in relation to the plant growth in the non-fumigated soil. All of the variables met the assumptions of normality and homogeneity and were subjected to analysis of variance. The significance of the means was determined by the Tukey test at 5% probability.

Results and discussion

In general, the weeds showed better development in the fumigated soil (Table 1), contrasting with other reports that have indicated that the presence of soil microbes promotes plant growth (TORSVIK; ØVREÅS, 2002).

However, the importance of the association between soil microorganisms and plants has been well established (ZAK et al., 2003), especially under conditions of low fertility, as with the substrate in this study. This plant-microbe interaction is often responsible for an improved ability to absorb nutrients and water from the soil and fix nitrogen.

However, it is known that many soil organisms that are efficient in assimilating nutrients can also cause injuries to several plant species. In this sense, Wright et al. (1998), evaluating the influence of mycorrhizal colonization on the biomass and photosynthesis in *Trifolium repens*, have found a direct relationship between the photosynthetic rate and the percentage of microbial association; however, the authors have found no evidence that the additional carbon was converted to biomass accumulation, suggesting that this carbon was allocated to the mycorrhizal fungi.

A reduction in the interactions between plants and microorganisms may be particularly beneficial to the former because it avoids the presence of pathogens in the rhizosphere. In this sense, soil fumigation becomes very important against certain species, such as *Rhizoctonia*, *Pythium* and *Phytophthora*, which have no host specificity and quickly kill plants enzymatically or cause injuries, impairing growth and development (MARTINS et al., 2003). Baptista et al. (2006) have reported that treatment of the substrate with methyl bromide significantly reduced the population of nematodes that cause disease in tomato plants.

We found that *C. echinatus*, *Echinochloa crus-galli*, *Eleusine indica*, *Lolium multiflorum* and *Zea mays* grew better in the fumigated soil (Table 1). It is known that plants and microorganisms have evolved together, and a system of chemical signaling, usually by the secretion of minerals, amino acids, organic acids and sugars, to enhance the growth of microorganisms exists in the rhizosphere, where 30% of the carbohydrates produced by photosynthesis is used in the maintenance of symbionts (BÜCKING; HEYSER, 2003). Therefore, it is likely that, for many plant species, including the weeds evaluated in the present study, a reduction of the microbiota associated with the rhizosphere is beneficial for the plant, perhaps due to better carbon utilization. In addition, grasses and cereal plants have more massive and aggressive root systems, allowing better soil exploration and, consequently, less reliance on symbionts.

Comparing the weeds to the crops, we found that the corn and beans were less affected functionally by the treatment of the soil with methyl bromide. It is probable that the genetic improvement of these species in recent years has contributed to this result.

Table 1. Plant height, leaf number, leaf area, shoot dry matter (SDM), root dry mass (RDM) and total dry mass (TDM) for different plant species, after cultivation for 50 days in soil fumigated with methyl bromide and non-fumigated soil.

Plant Species	Height	Leaves	Leaf Area	SDM	RDM	TDM
	-------------- % compared to plants grown in non-fumigated soil ----------------					
Ageratum conyzoides	133.04 a	107.89 bc	99.31 d	79.78 e	88.10 bcd	84.09 c
Bidens pilosa	104.94 ab	216.67 a	194.69 c	104.21 cde	68.72 d	86.72 c
Cenchrus echinatus	103.26 ab	114.19 bc	80.00 d	111.08 bcde	111.26 ab	111.15 ab
Conyza bonariensis	52.17 c	49.15 d	60.87 d	37.04 f	81.15 bcd	58.94 d
Echinochloa crus-galli	118.93 ab	102.88 bc	222.41 bc	157.56 a	104.58 abc	131.35 a
Eleusine indica	113.39 ab	138.42 bc	275.55 b	138.37 abc	128.31 a	134.16 a
Ipomoea grandifolia	103.26 ab	93.41 cd	107.95 d	103.80 de	109.25 abc	99.14 bc
Lolium multiflorum	91.27 b	146.91 b	393.31 a	132.72 abcd	68.93 d	108.59 ab
Phaseolus vulgaris	91.32 b	102.56 bc	98.68 d	98.46 e	96.11 bcd	101.30 bc
Zea mays	95.53 b	105.88 bc	100.42 d	144.32 ab	79.44 cd	112.00 ab
C.V. (%)	--15.30--	--18.74--	--25.54--	--13.92--	--14.66--	--11.23--

Means followed by same letters in each column do not differ by Tukey test at 5% probability.

A dependence on microorganisms is inferred in plants that exhibited growth effects by the soil fumigation. Such an occurrence was observed for *Conyza bonariensis*, which showed a lower nutrient content after growing in the soil treated with methyl bromide (Table 2).

We observed a higher accumulation of phosphorus in the grasses grown in the substrate treated with methyl bromide (Table 2), whereas *B. pilosa* and *C. bonariensis* (Table 2) were negatively affected. Considering the values of the dry matter and nutrient content together, a proportional relationship between root growth and the phosphorus accumulation in tissues was evident for *B. pilosa* and *C. bonarienesis* (Tables 1 and 2). Working with sterilized soil, Aguiar et al. (2004) have observed that, for *Prosopis juliflora*, the level of phosphorus in its tissues was irrelevant as a function of facultative association with mycorrhizae-forming fungi. Therefore, it is probable that *B. pilosa* and *C. bonariensis* are dependent on this association. Among the other nutrients, a function of the discrepancy of the values found in the comparison between *B. pilosa* (164.58% more than its control) and *C. echinatus* (30.08% less, also based on its control) was found for sulfur (Table 2).

With regard to macronutrients, a comparison between the plant species revealed that *C. bonariensis* showed low values when grown in the soil treated with methyl bromide (Table 2). Recently, this weed has received attention due to the difficulty of its control, particularly by chemical methods, which is associated with a higher occurrence of populations of herbicide-resistant biotypes. It should be emphasized that cultural control, including crop rotation, is the most efficient method to control this plant species (NANDULA et al., 2006).

The micronutrient manganese demonstrated elevated accumulation levels in all of the evaluated species grown in soil treated with methyl bromide (Table 2). The levels of these increases ranged from 17.95% (*C. bonariensis*) to 421.18% (*B. pilosa*). In the soil, oxi-reduction reactions strongly influence the availability of some nutrients to plants, which, in turn, are also strongly influenced by the microorganisms present. According to Tisdale et al. (1985), edaphic microbiota can promote the oxidation of manganese (Mn^{2+}) in stable complexes with soil organic matter, making it unavailable to plants and resulting in high levels of nutrients in the sterilized soil. Manganese is absorbed in the reduced form (Mn^{2+}), as opposed to the oxidized form (Mn^{4+}) present in the insoluble complexes (MARSCHNER, 1995), and the balance between them is governed by the soil microbial community, which is absent or occurs in lower quantities in soil treated with methyl bromide.

Among all of the micronutrients, *C. bonariensis* showed the lowest values for the relative contents of zinc, iron, manganese and copper; thus, we infer a high dependency of this species on soil microorganisms. In addition to decreasing the relative height, leaf area and dry weight of the plants, soil treatment with methyl bromide also promoted less accumulation of nutrients in leaf tissues (Tables 1 and 2).

Table 2. Accumulation of macro and micronutrients in ten plant species after development for 50 days in soil fumigated with methyl bromide and non-fumigated.

Plant species	P	K	S	Ca	Mg
	% em relação às plantas cultivadas em solo não-fumigado				
Agerathum conyzoides	144.09 b	135.13 ab	161.65 b	103.70 bc	106.21 b
Bidens pilosa	78.69 cd	113.60 b	264.58 a	168.61 a	81.51 c
Cenchrus echinatus	188.19 a	165.48 a	69.92 d	143.78 ab	49.74 d
Conyza bonariensis	68.95 d	54.85 d	74.05 d	48.67 d	40.69 d
Echinocloa crus-galli	197.48 a	161.89 a	121.11 c	128.86 b	92.25 bc
Eleusine indica	159.67 b	165.41 a	86.82 d	123.21 b	136.45 a
Ipomoea. grandifolia	157.94 b	157.37 a	174.69 b	94.08 c	114.39 b
Lolium multiflorum	110.64 c	108.96 bc	142.85 bc	96.95 c	103.71 b
Phaseolus vulgaris	94.71 c	95.70 c	110.27 c	92.21 c	107.56 b
Zea mays	198.42 a	158.71 a	123.33 c	140.81 ab	138.14 a
CV (%)	-- 9.43--	---6.2--	--8.76--	--8.45--	--10.12--

Plant species	Zn	Fe	Mn	Cu
Agerathum conyzoides	140.32 b	169.19 a	258.94 d	151.11 b
Bidens pilosa	132.59 b	100.57 bc	521.18 a	94.26 d
Cenchrus echinatus	108.88 c	148.31 a	201.75 e	217.74 a
Conyza bonariensis	57.34 d	66.33 d	117.95 f	52.40 e
Echinocloa crus-galli	142.22 b	87.10 c	186.25 e	135.15 bc
Eleusine indica	182.25 a	105.70 bc	308.86 c	132.02 bc
Ipomoea. grandifolia	130.96 b	114.02 b	410.67 b	125.74 c
Lolium multiflorum	116.03 bc	83.32 cd	191.06 e	140.11 bc
Phaseolus vulgaris	92.16 c	93.33 bc	168.28 e	98.80 d
Zea mays	173.8 a	101.19 bc	222.18 d	193.37 a
CV (%)	--4.12--	--9.75--	--15.11--	--7.68--

Means followed by same letters in each column do not differ by Tukey test at 5% probability.

Species of the genus *Conyza* noted for infest abandoned areas, pasture and perennial crops. (THEBAUD; ABBOTT, 1995). This observation implies a preference of the species for less 'disturbed' environments. In a review on *C. bonariensis* by Lazaroto et al. (2008), it has been reported that this species demonstrates efficient ecological adaptability under conservation systems, such as tillage or minimum soil tillage. According to the authors, such systems induce higher selection pressure when using desiccants, especially glyphosate, in the pre-planting stage, and this hypothesis would explain the steep rise of cases of resistant biotypes. Thus, a detailed study of the relationship between *C. bonariensis* and soil microorganisms may assist in developing strategies for managing this weed.

Fifty days after sowing, four species reached reproductive phenological stadium, being that soil treatment with methyl bromide anticipated the process in one week for *B. pilosa*, *E. indica* and *C. echinatus* (Table 3). It has been reported that some weeds are able to induce their reproductive cycle as a function of soil and climatic stresses (JONES et al., 2009). Thus, for these species, soil fumigation may have prevented or reduced access to one or more environmental resources, resulting in stress and the anticipation of the reproductive phase.

Table 3. Number of days to flowering in four weed species grown for 50 days in soil fumigated with methyl bromide and non-fumigated soil.

Soil	Interval between seeding and flowering (days)			
	Bidens pilosa	*Eleusine indica*	*Ageratum conyzoides*	*Cenchrus echinatus*
Non-fumigated	44.75 a	42.25 a	43.50 a	48.25 a
Fumigated	35.50 b	37.25 b	43.75 a	41.75 b
C.V. (%)	4.71			

Means followed by same letters in each column do not differ by F test at 5% probability.

Conclusion

From the results presented here, it can be concluded that soil treatment with methyl bromide favored the grass species, *Conyza bonariensis*, which was dependent on the soil biota for normal development. The weeds, *Bidens pilosa*, *Eleusine indica* and *Cenchrus echinatus*, anticipated the reproductive stadium when grown in fumigated soil. Under this treatment, the content of accumulated phosphorus was lower in *Bidens pilosa* and *Conyza bonariensis*. Furthermore, comparing the weeds and crops, the corn and beans suffered fewer overall effects of soil fumigation.

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References

AGRIOS, G. N. **Plant Pathology**. 4th ed. San Diego: Academic Press, 1997.

AGUIAR, R. L. F.; MAIA, L. C.; SALCEDO, I. H.; SAMPAIO, E. V. S. B. Interação entre fungos micorrízicos arbusculares e fósforo no desenvolvimento da algaroba [*Prosopis juliflora* (Sw) DC]. **Revista Árvore**, v. 28, n. 4, p. 589-598, 2004.

AOAC-Association of Official Analytical Chemists. **Official methods of analysis**. 12th ed. Washigton, D.C.: AOAC, 1975.

BAPTISTA, M. J.; SOUZA, R. B.; PEREIRA, W.; CARRIJO, O. A.; VIDAL, M. C.; CHARCHAR, M. J. Solarização do solo e biofumigação no cultivo protegido de tomate. **Horticultura Brasileira**, v. 24, n.1, p. 47-52, 2006.

BIANCHI, M. A.; FLECK, N. G.; LAMEGO, F. P. Proporção entre plantas de soja e plantas competidoras e as relações de interferência mútua. **Ciência Rural**, v. 36, n. 5, p. 1380-1387, 2006.

BRAGA, J. M.; DE FELLIPO, B. V. Determinação espectrofotométrica de fósforo em extratos de solos e plantas. **Revista Ceres**, v. 21, n. 1, p. 73-85, 1974.

BÜCKING, H.; HEYSER, W. Uptake and transfer of nutrients in ectomycorrhizal associations: interactions between photosynthesis and phosphate nutrition. **Mycorrhiza**, v. 13, n. 2, p. 59-68, 2003.

DUDA, G. P.; GUERRA, J. G. M.; MONTEIRO, M. T.; DE-POLLI, H.; TEIXEIRA, M. G. Perennial herbaceous legumes as live soil mulches and their effects on C, N and P of the microbial biomass. **Scientia Agricola**, v. 60, n. 1, p. 139-147, 2003.

JACKSON, M. L. **Soil chemical analysis**. New Jersey: Prentice Hall, Inc., 1958.

JONES; G.; CHARLES, M.; BOGAARD, A.; HODGSON, J. Crops and weeds: the role of weed functional ecology in the identification of crop husbandry methods. **Journal of Archaeological Science**, v. 37, n. 1, p. 70-77, 2009.

KAO, D. W.; KO, W. H. Nature of suppression of *Pythium splendens* in a pasture soil in South Kahala, Hawaii. **Phytopathology**, v. 73, n. 4, p. 1284-1289, 1983.

LAZAROTO, C. A.; FLECK N. G.; VIDAL, R. A. Biologia e ecofisiologia de buva (*Conyza bonariensis* e *Conyza canadensis*). **Ciência Rural**, v. 38, n. 3, p. 852-860, 2008.

MARSCHNER, H. **Mineral nutrition of higher plants**. 2nd ed. New York: Academic Press, 1995.

MARTINS, M. V. V.; SILVEIRA, S. F.; CARVALHO, A. J. C.; SOUZA, E. F. Erradicação de escleródios de Sclerotium rolfsii em substratos tratados em coletores solares, em Campos dos Goytacazes-RJ. **Revista Brasileira de Fruticultura**, v. 25, n. 3, p. 421-424, 2003.

NANDULA, V. K.; EUBANK, T. W.; POSTON, D. H.; KOGER, C. H.; REDDY, K. N. Factores affeting germination of horseweed (*Conyza Canadensis*). **Weed Science**, v. 54, n. 5, p. 898-902, 2006.

RIZZARDI, M. A.; FLECK, N. G.; VIDAL, A. R.; MEROTTO, J. R. A.; AGOSTINETTO, D. Competition between weeds and crops by soil resources. **Ciência Rural**, v. 31, n. 4, p. 707-714, 2001.

SARRUGE, J. R.; HAAG, H. P. **Análise química em plantas**. Piracicaba: Esalq, 1974.

SCHER, F. M.; BAKER, R. Mechanism of biological control in a *Fusarium* suppressive soil. **Phytopathology**, v. 70, n. 5, p. 412-417, 1980.

SILVA, P.; NAHAS, E. Bacterial diversity in soil response to different plants, phosphate fertilizers and liming. **Brazilian Journal of Microbiology**, v. 33, n. 4, p. 304-310, 2002.

SINDAG-Sindicato Nacional da Indústria de Produtos para Defesa Agrícola. Available from: <http://www.sindag.com.br/noticia.php?News_ID=1933>. Access on: June 22, 2010.

THEBAUD, C.; ABBOTT, R. J. Characterization of invasive *Conyza* species (Asteraceae) in Europe: quantitative trait and isozyme analysis. **American Journal of Botany**, v. 82, n. 3, p. 360-368, 1995.

TISDALE, S. L.; NELSON, W. L.; BEATON, J. D. **Soil fertility and fertilizers**. New York: McMillan Publishing Company, 1985.

TORSVIK, V.; ØVREÅS, L. Microbial diversity and function in soil: from genes to ecosystems. **Current Opinion in Microbiology**, v. 5, n. 2, p. 240-245, 2002.

WRIGHT, D. P.; SCHOLES, J. D.; READ, D. J. Effects of VA mycorrhizal colonization on photosynthesis and biomass production of *Trifolium repens* L. **Plant, Cell and Environment**, v. 21, n. 2, p. 209-216, 1998.

ZAK, D. R.; HOLMES, W. E.; WHITE, D. C.; PEACOCK, A. D.; TILMAN, D. Plant diversity, soil microbial communities, and ecosystem function: are there any links? **Ecology**, v. 84, n. 8, p. 2042-2050, 2003.

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